Mobile communications: Ideas that change the world

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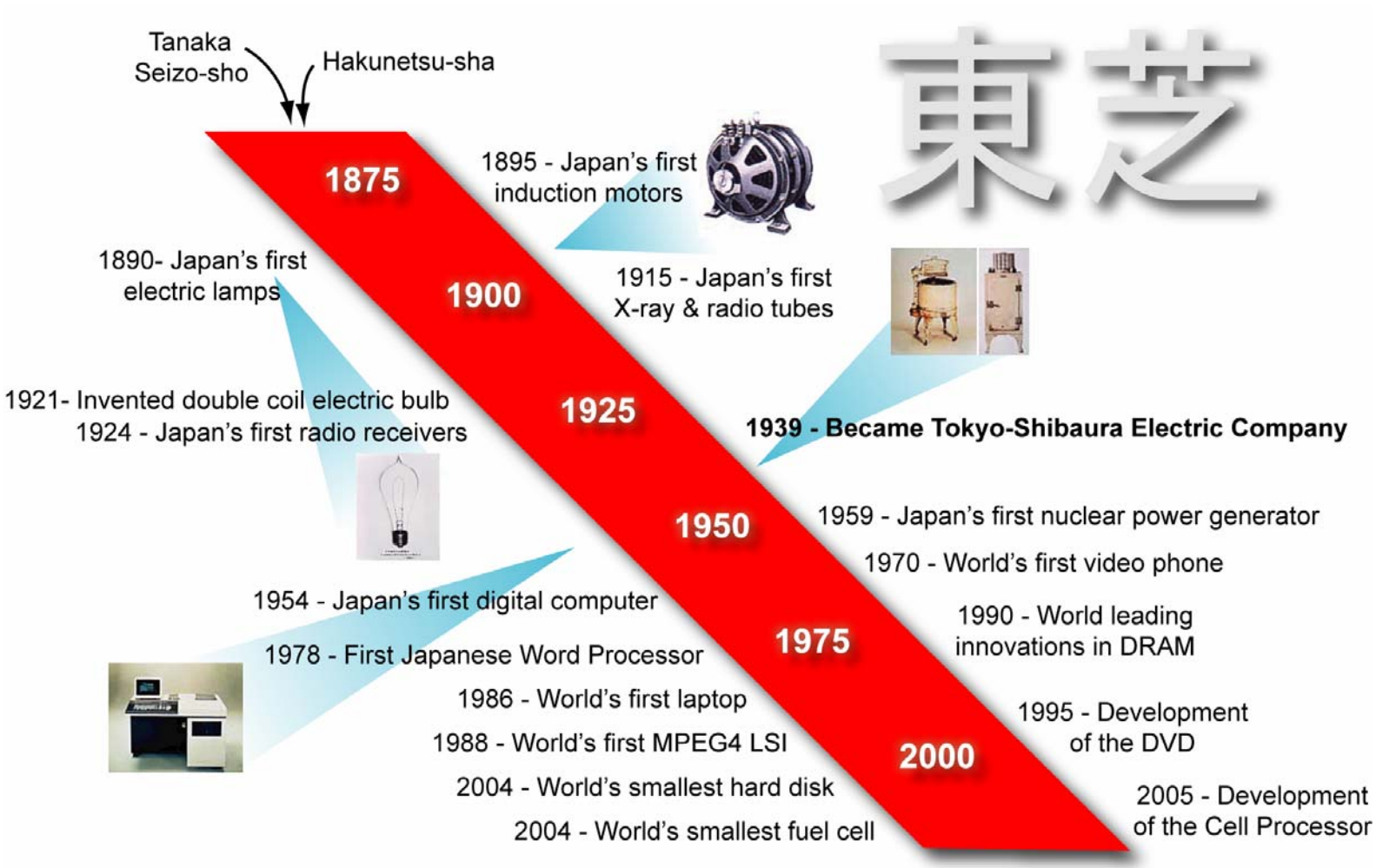
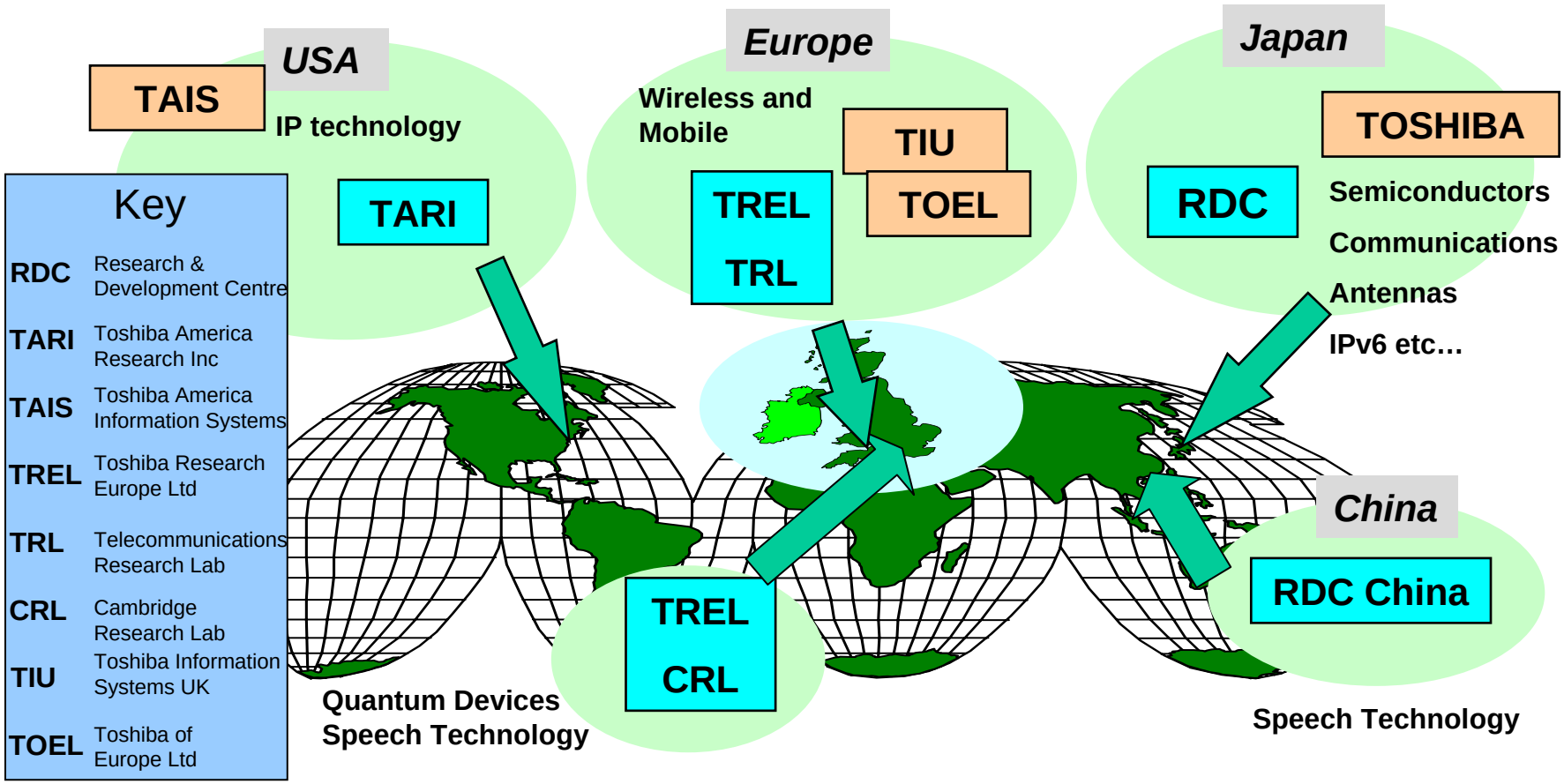
"Reality is merely an illusion, albeit a very persistent one!"

"*Commercialisation* is merely an illusion, albeit a very *time-consuming and costly* one!"

Toshiba – history of innovation



Toshiba's Global R&D structure



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Centre for Communications Research

- Interdisciplinary research centre within Department of Electrical and Electronic Engineering
- Established in 1987
- Successful model repeated around the world
- Currently home to over 120 researchers involved in areas including:
  - Wireless Communications
  - Electromagnetics
  - Signal processing
  - Networks and Protocols
  - Photonics


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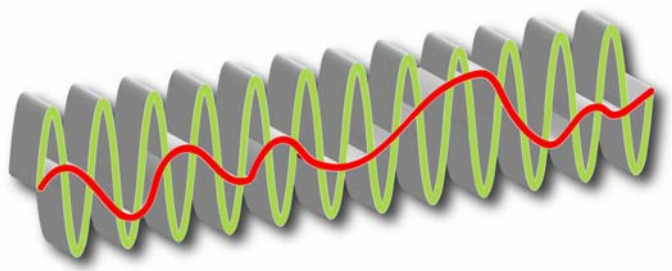


Modulation

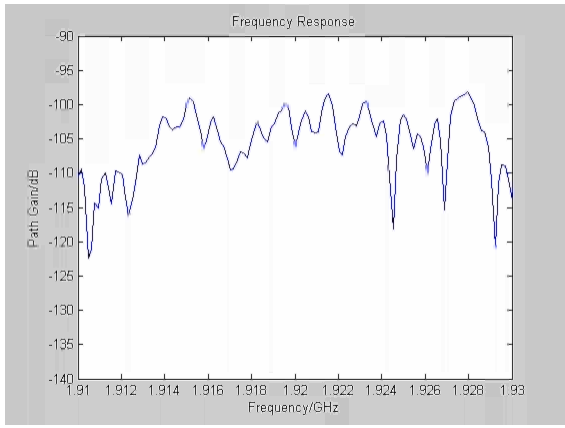
A change in direction: Early 1970s

- Importance of diversity
  - Gas discharges, semiconductors and their applications to radar, telecoms and high-speed digital circuits
- During the Fuel Crisis of 1974
  - Cost of oil rocketing
  - Impacting business
- Changes to allocation of spectrum for mobile communications
  - Continuous reduction over several years
- What role could efficient mobile communications play?

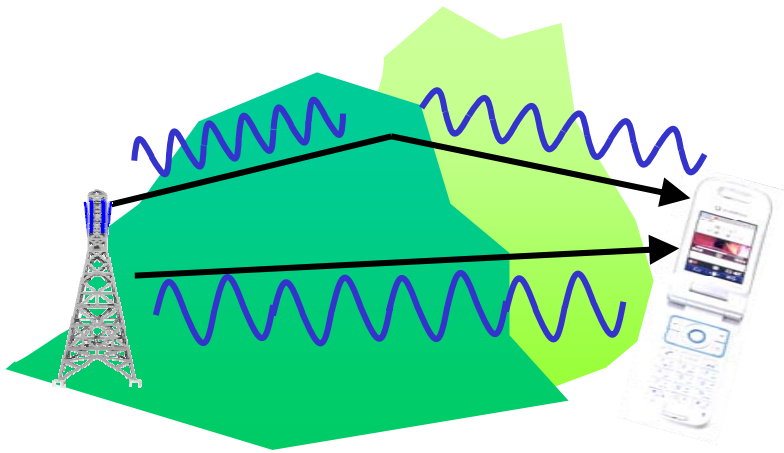
An apparent dead end

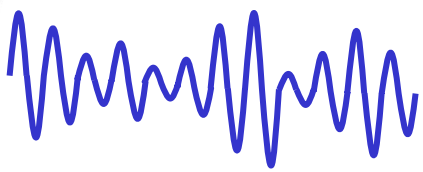
- Wireless communications world-wide largely based on Frequency Modulation (FM)
- AM not recognised internationally for mobile
- Mobile communications bandwidth continually being reduced
- The only solution was to increase spectrum
  - Apparently too difficult to solve the problems of transmission
- Alternative approaches required

Illustration of multipath fading distortion



Conventional AM Radio

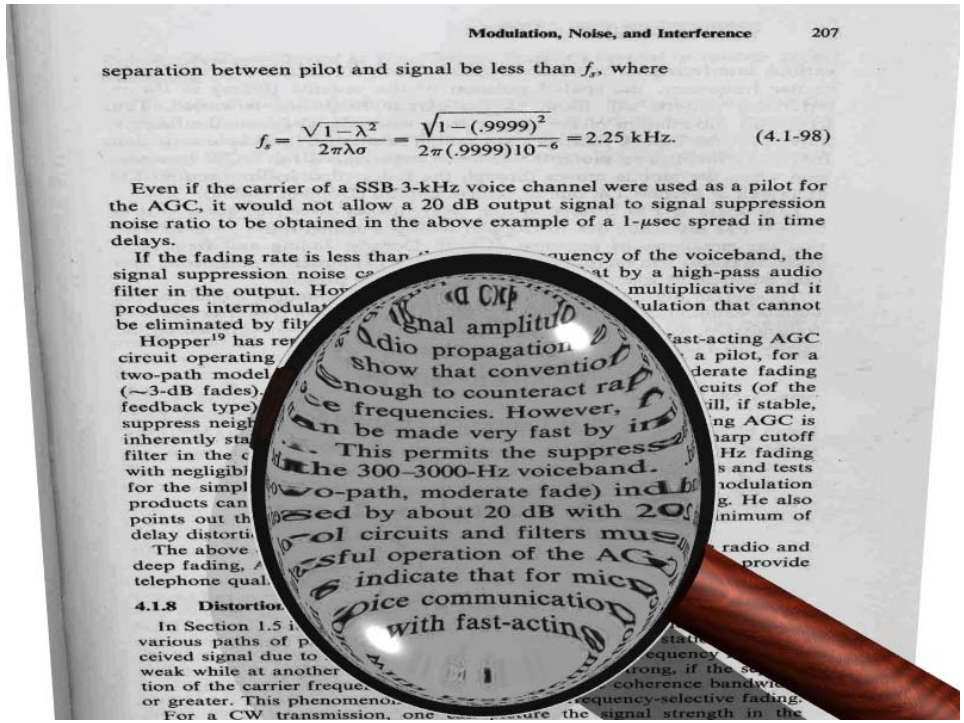




Faded signal

Achieving the impossible?

"The above considerations indicate that for microwave mobile radio and deep fading, AM and SSB voice communication channels cannot provide telephone quality signals, even with fast-acting AGC of any type."



Modulation, Noise, and Interference 207

separation between pilot and signal be less than f_s, where

$$f_s = \frac{\sqrt{1-\lambda^2}}{2\pi\lambda\sigma} = \frac{\sqrt{1-(.9999)^2}}{2\pi(.9999)10^{-6}} = 2.25 \text{ kHz.} \qquad (4.1\text{-}98)$$

Even if the carrier of a SSB 3-kHz voice channel were used as a pilot for the AGC, it would not allow a 20 dB output signal to signal suppression noise ratio to be obtained in the above example of a 1-μsec spread in time delays.

If the fading rate is less than ... quency of the voiceband, the signal suppression noise ca... ...t by a high-pass audio filter in the output. Ho... ...multiplicative and it produces intermodula... ...ulation that cannot be eliminated by fil...

Hopper[19] has re... ...fast-acting AGC circuit operating ... ...a pilot, for a two-path model ... ...derate fading (~3-dB fades)... ...cuits (of the feedback type)... ...ill, if stable, suppress neigh... ...ng AGC is inherently sta... ...harp cutoff filter in the c... ...Hz fading with negligibl... ...s and tests for the simpl... ...odulation products can ... ...g. He also points out th... ...inimum of delay distorti...

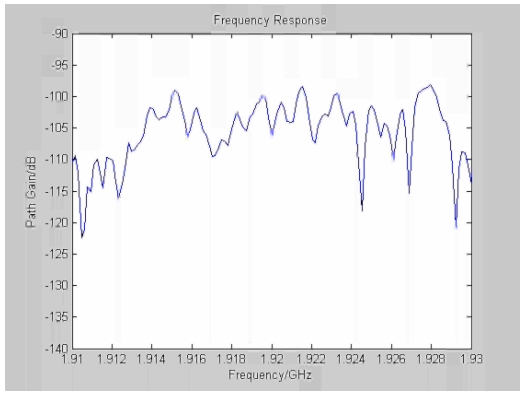
The above ... ...radio and deep fading, A... ...provide telephone qual...

4.1.8 Distortio...

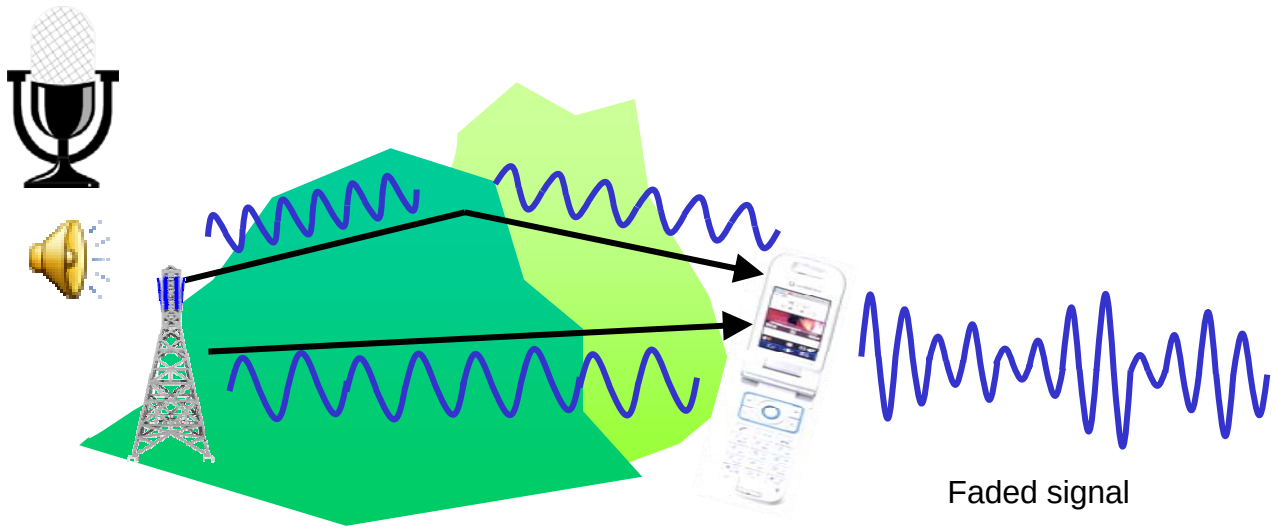
In Section 1.5 i... various paths of p... ceived signal due to ... weak while at another ... tion of the carrier freque... or greater. This phenomeno... ...requency-selective fading. For a CW transmission, one ... ...ure the signal strength in the

Microwave Mobile Communications, William C Jakes (ed.), pub. John Wiley & Sons, 1974

Solution to multipath fading distortion



Conventional AM Radio



Faded signal

Feed-forward Signal Regeneration (FFSR) as employed in US West demonstrator

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Early mobile developments

Image from PYE Museum Website http://www.qsl.net/gm8aob/group.htm


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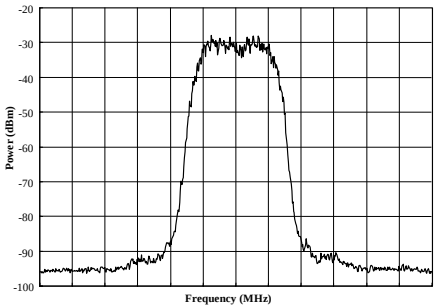
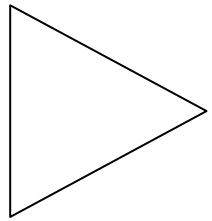
Amplifiers

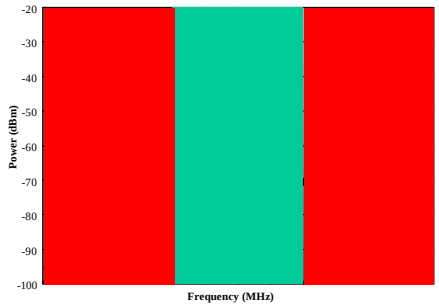
RF Amplification for Linear Modulation

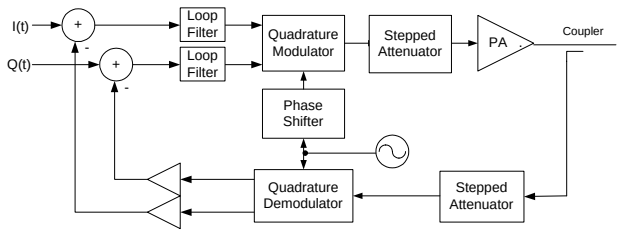


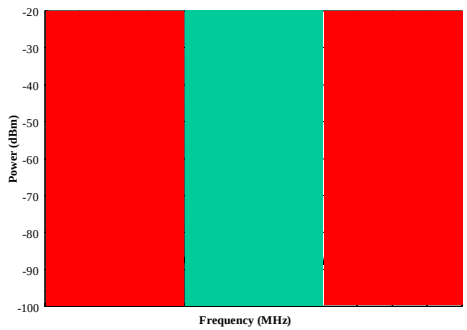
Linear Modulated waveform (DQPSK)

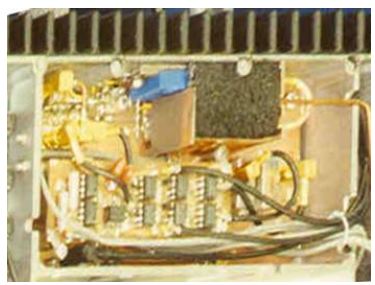


Conventional RF Amplifier



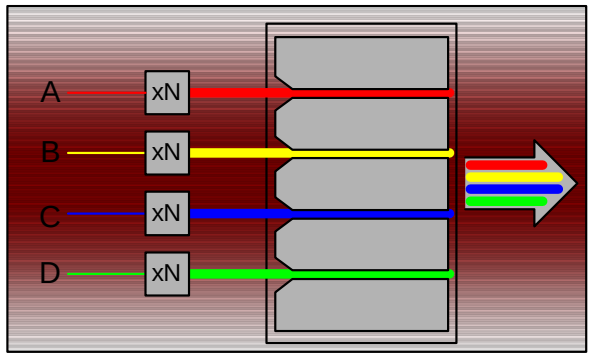






Linearised RF Amplifier

Basestations: Further need for linear amplifiers

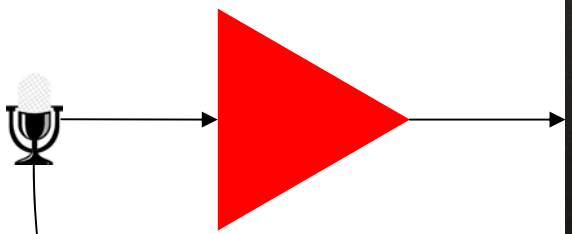


Cavity Combiner

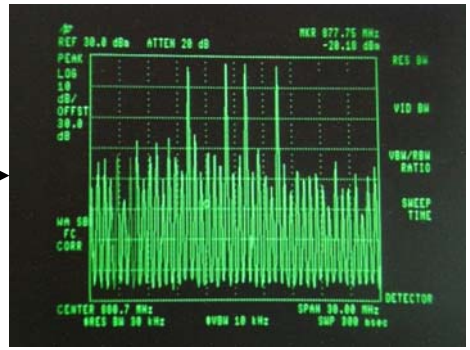
- Need to support multiple high power transmissions to a single antenna

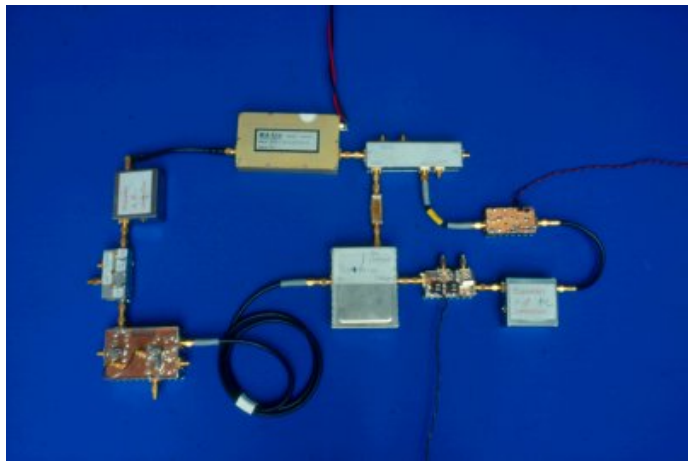
Lack of Flexibility

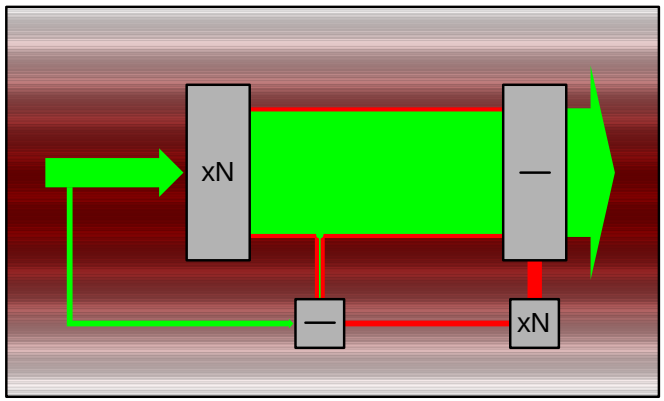
Broadband Linearised Amplifier



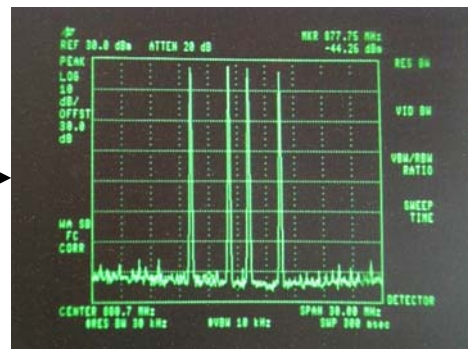
Conventional Amplifier







Feed-forward Linearised Amplifier

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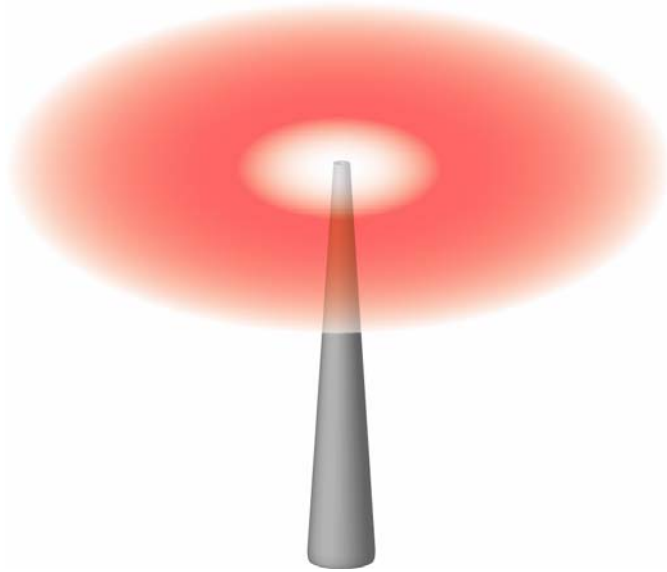
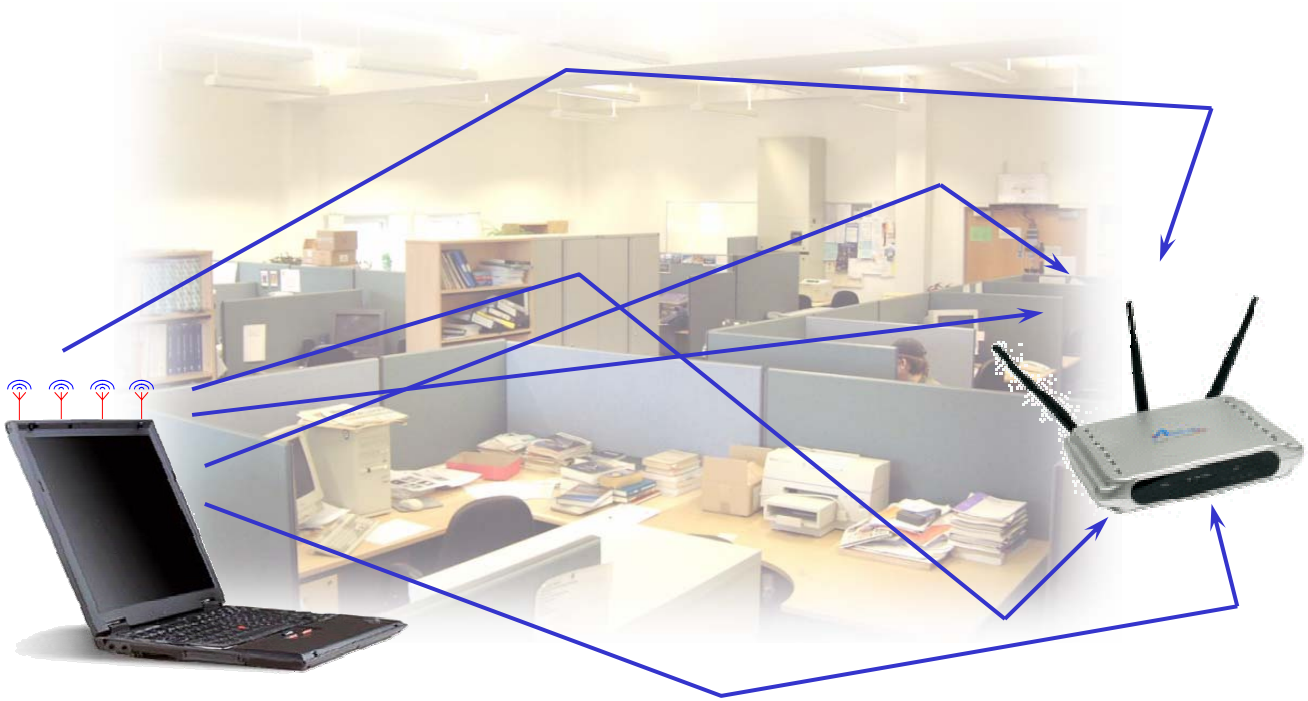


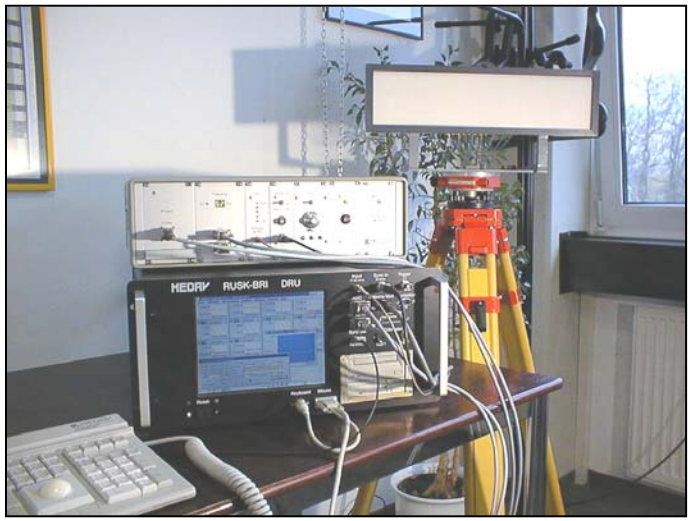
MIMO

MIMO: Multiple Input Multiple Output

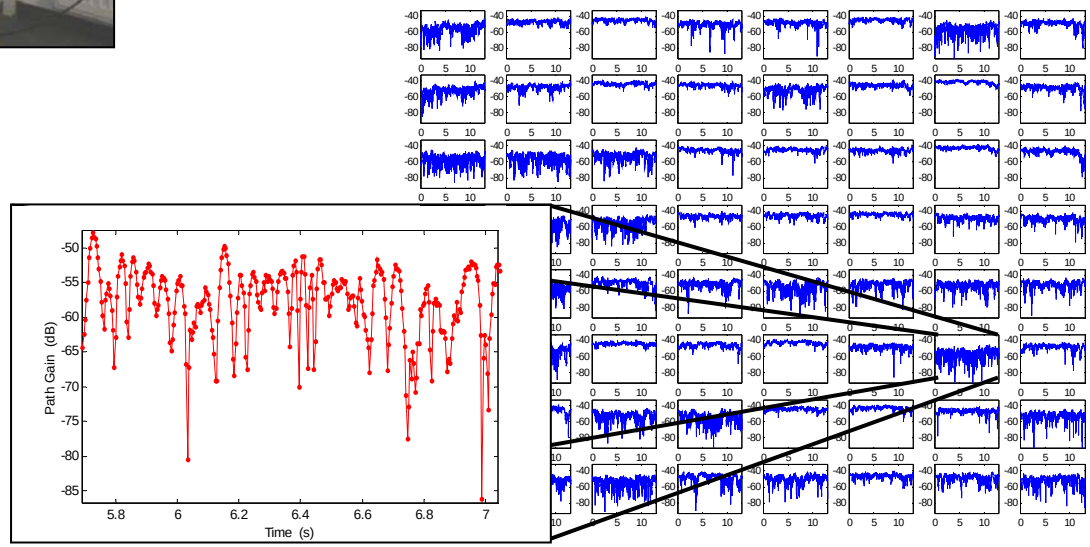


- High data rates
- Spectrum efficient
- Better performance and coverage

MIMO: Propagation measurement & analysis

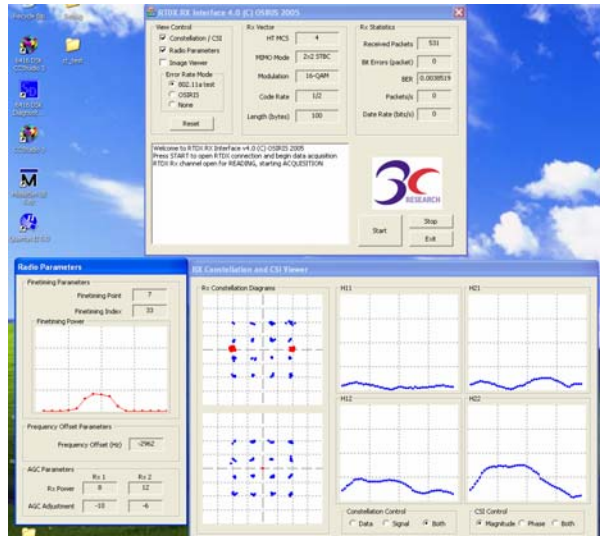


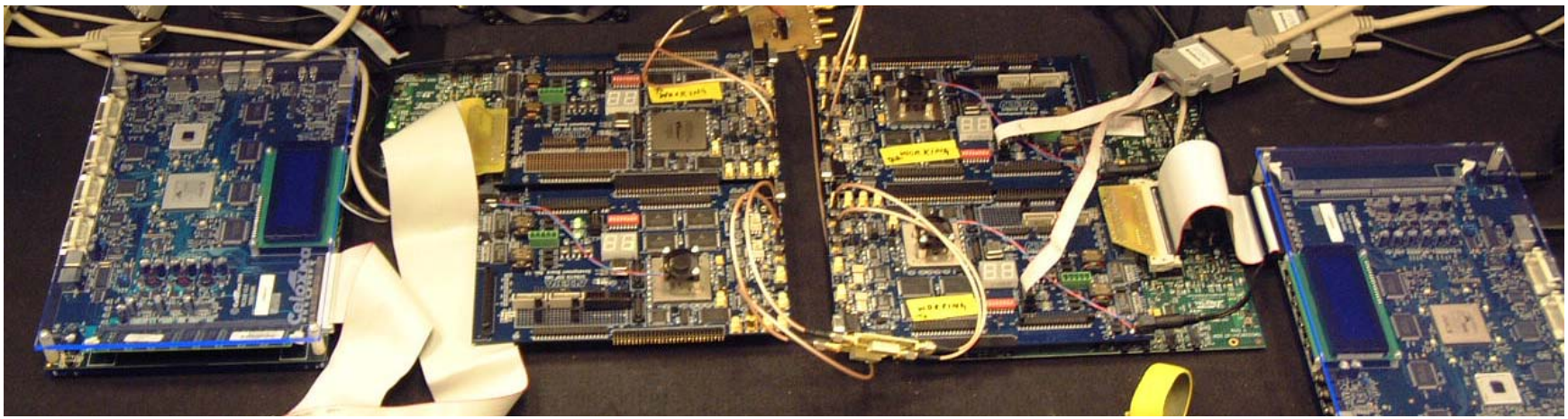
- State of the art channel sounding
- Extensive analysis & modelling
- Fundamental understanding of MIMO communication
- Realistic simulations



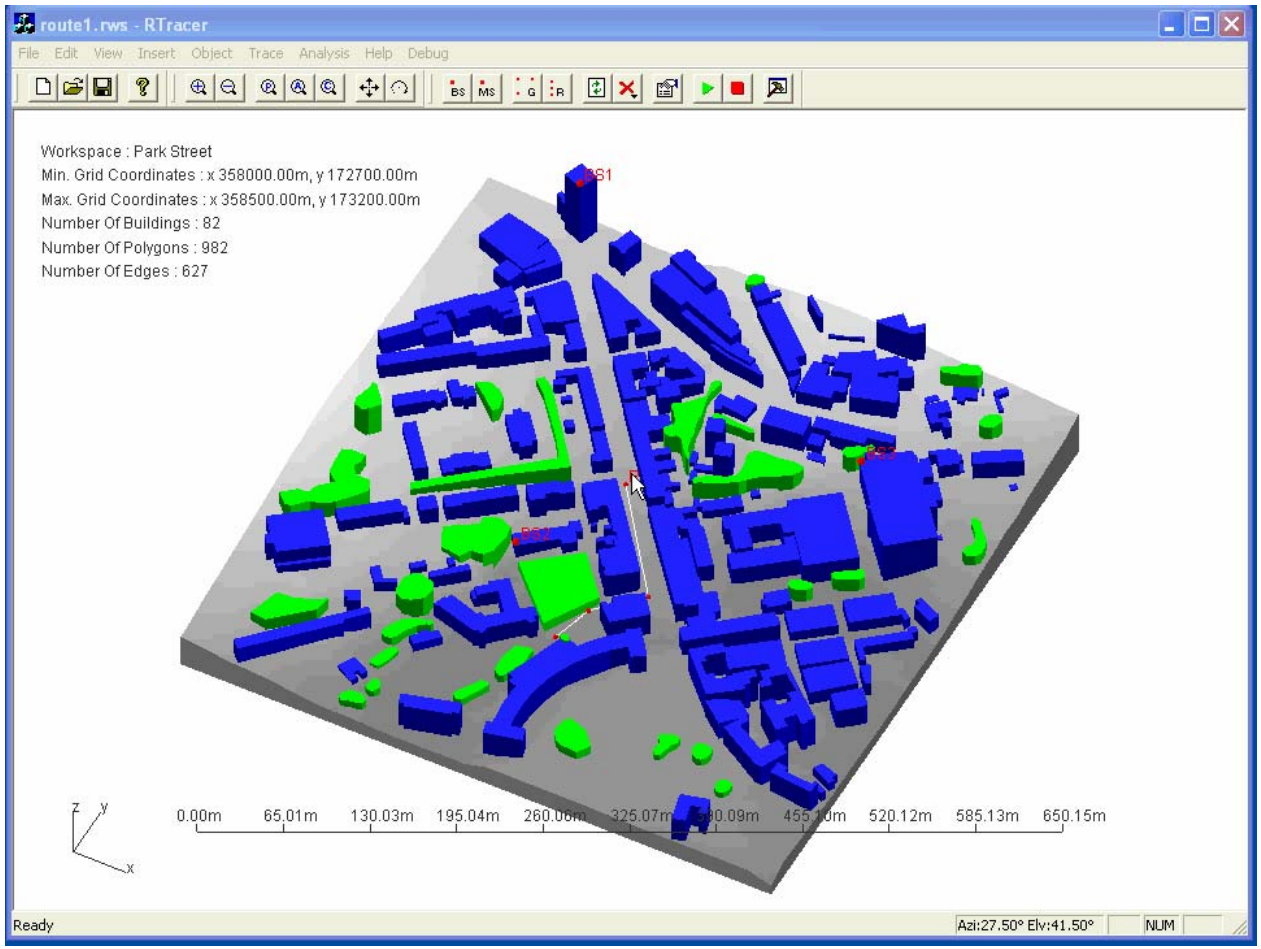
MIMO: Real-time MIMO hardware testbed

- DTI funded project
- Transfer of knowledge, skills and expertise from theory to simulation, through to implementation





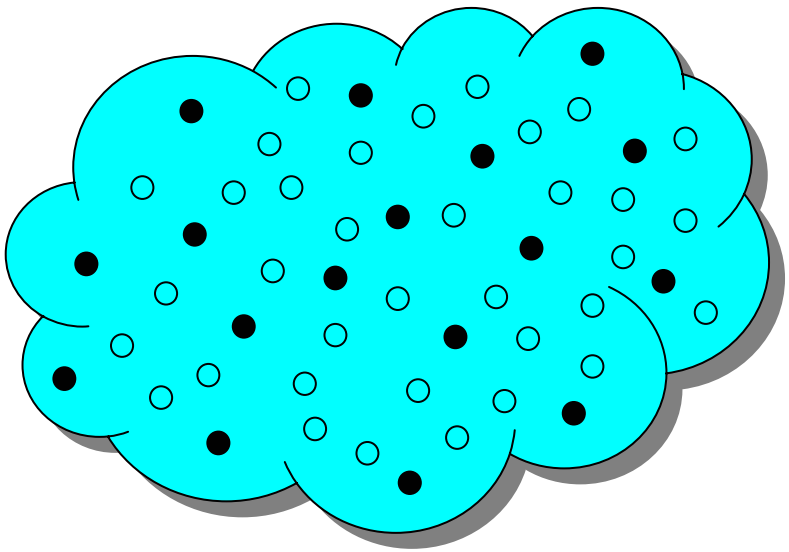
Raytracing for propagation prediction

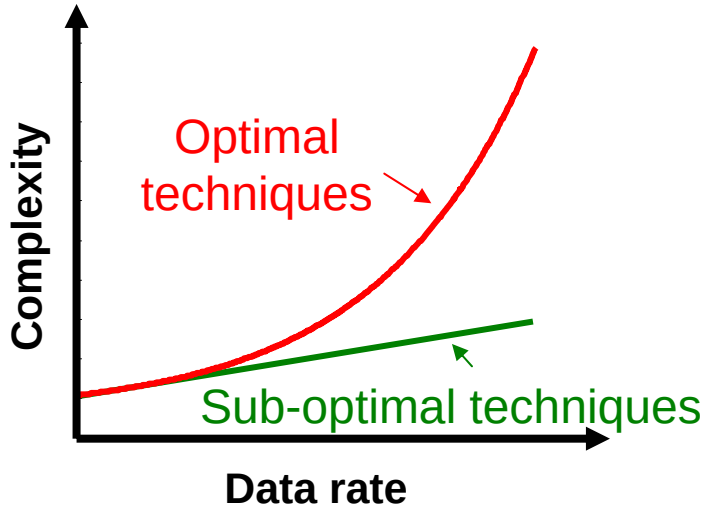


Reduced complexity decoders

Reduced complexity MIMO decoders

Optimal technique
- Search all possibilities
- Exponential complexity



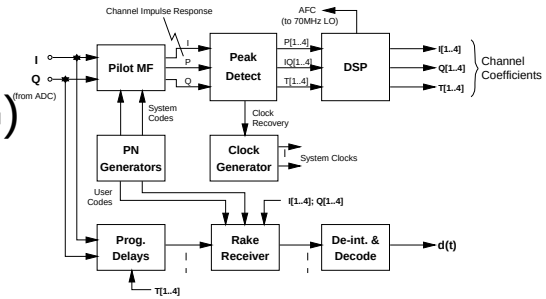


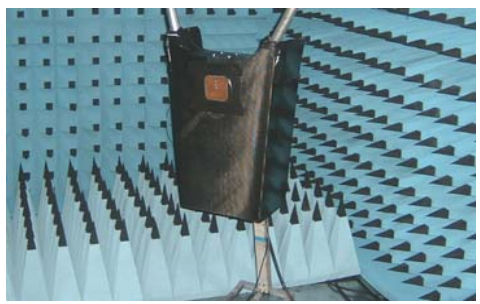
Statistical technique
- Only consider most likely candidates
- Reduced complexity

Further examples of innovation

Speech Scrambler

Wideband CDMA (pre 3G)





Conformal Antennas

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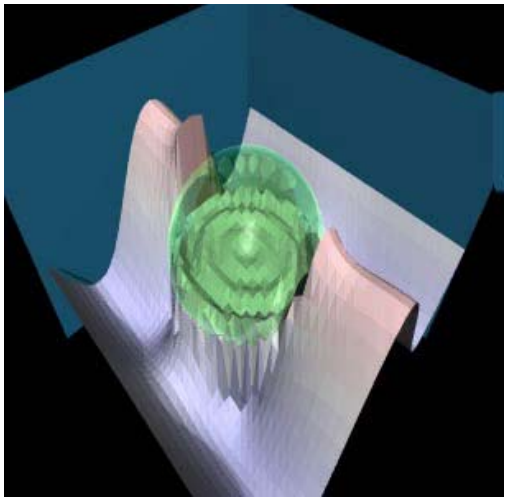
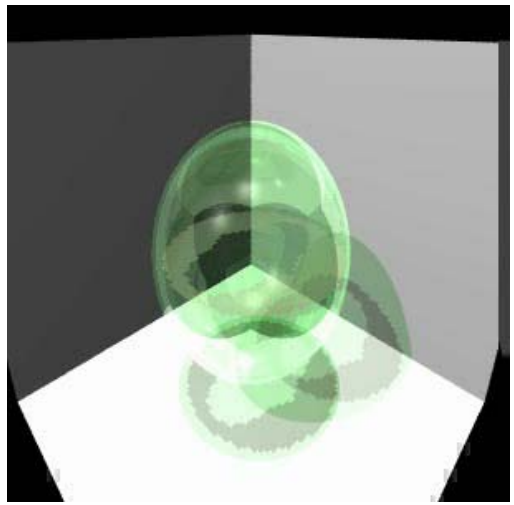
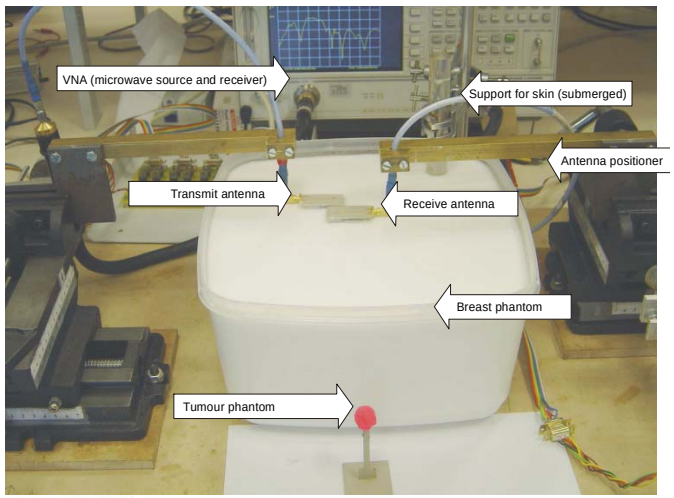
Further examples of innovation

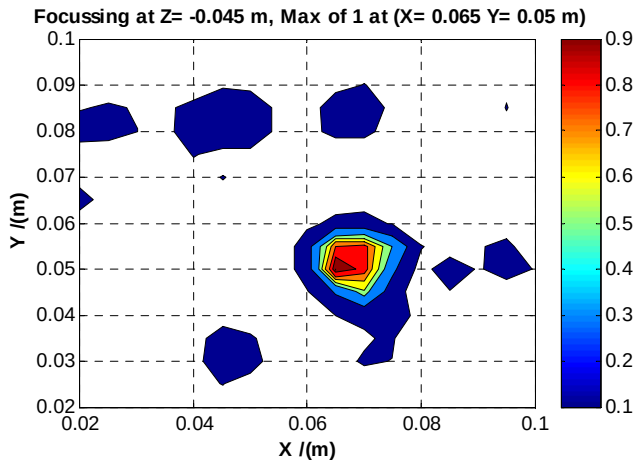


Electromagnetic wave analysis using FDTD





Non invasive detection of Breast Cancer



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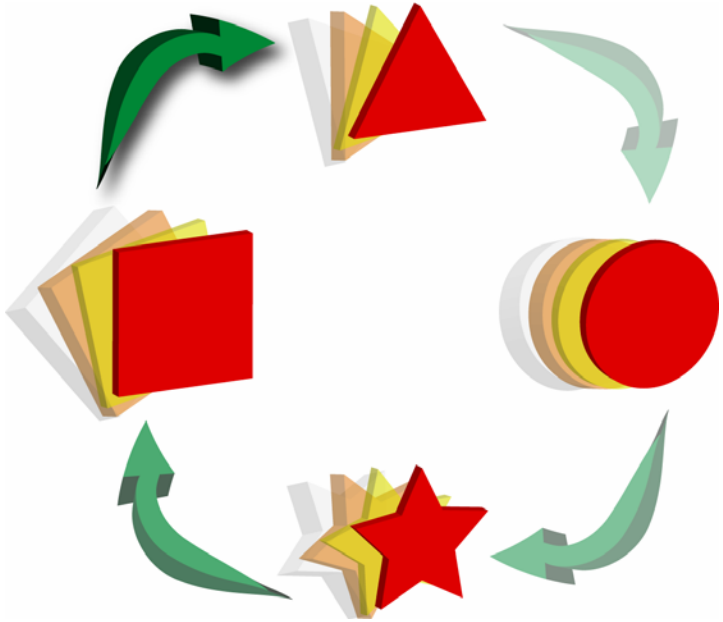
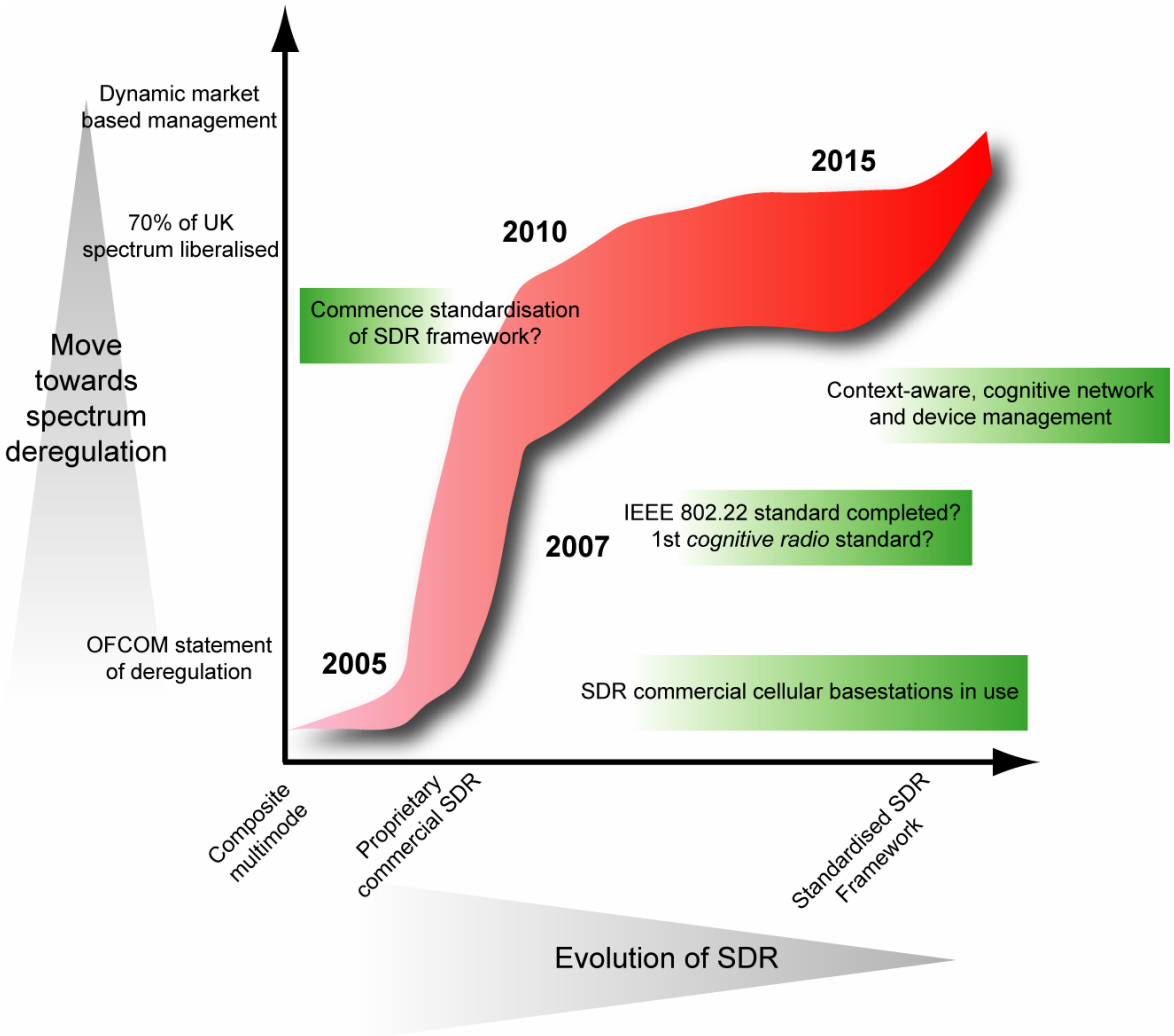
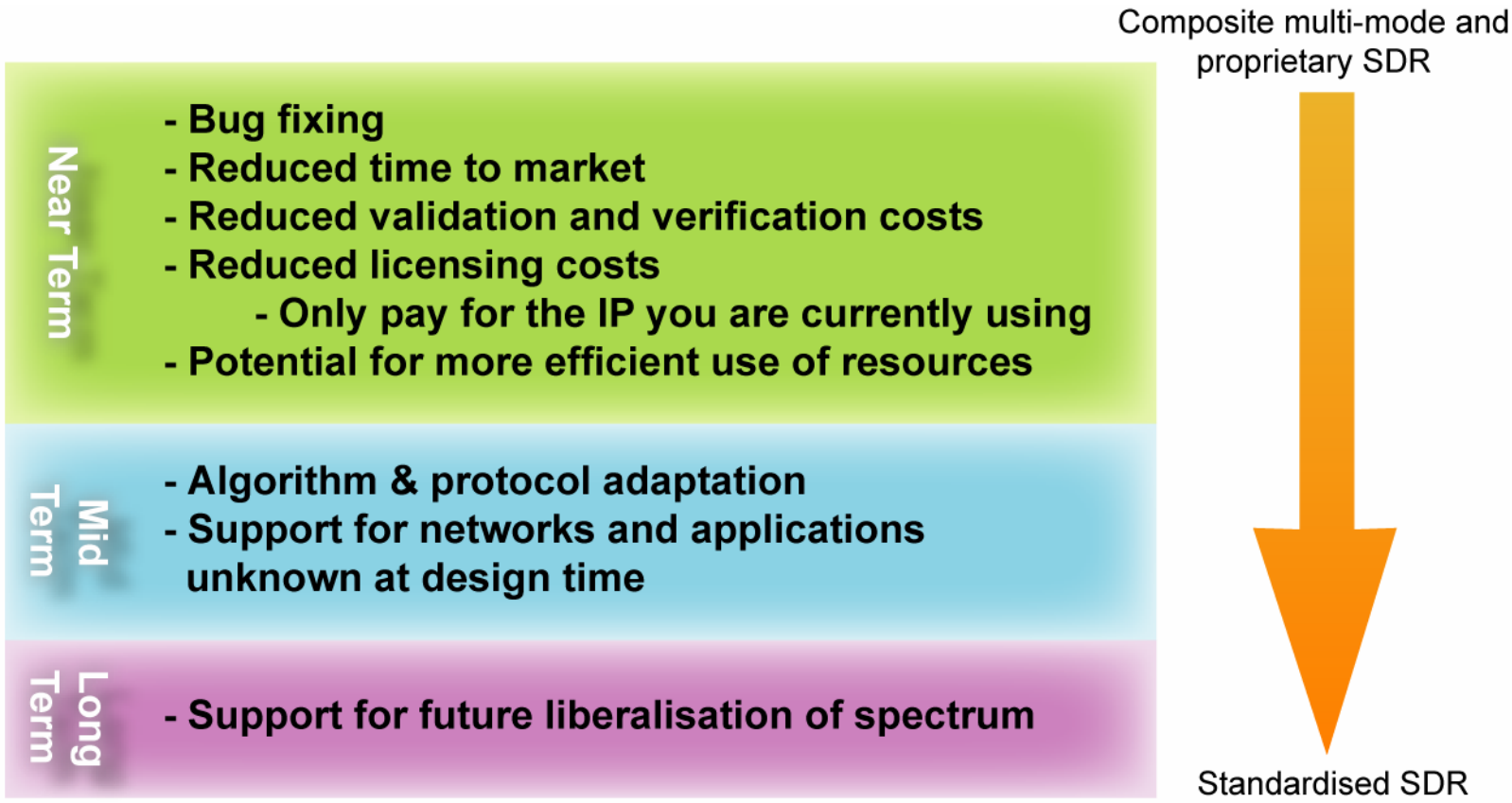


Reconfigurability

Reconfigurability roadmap

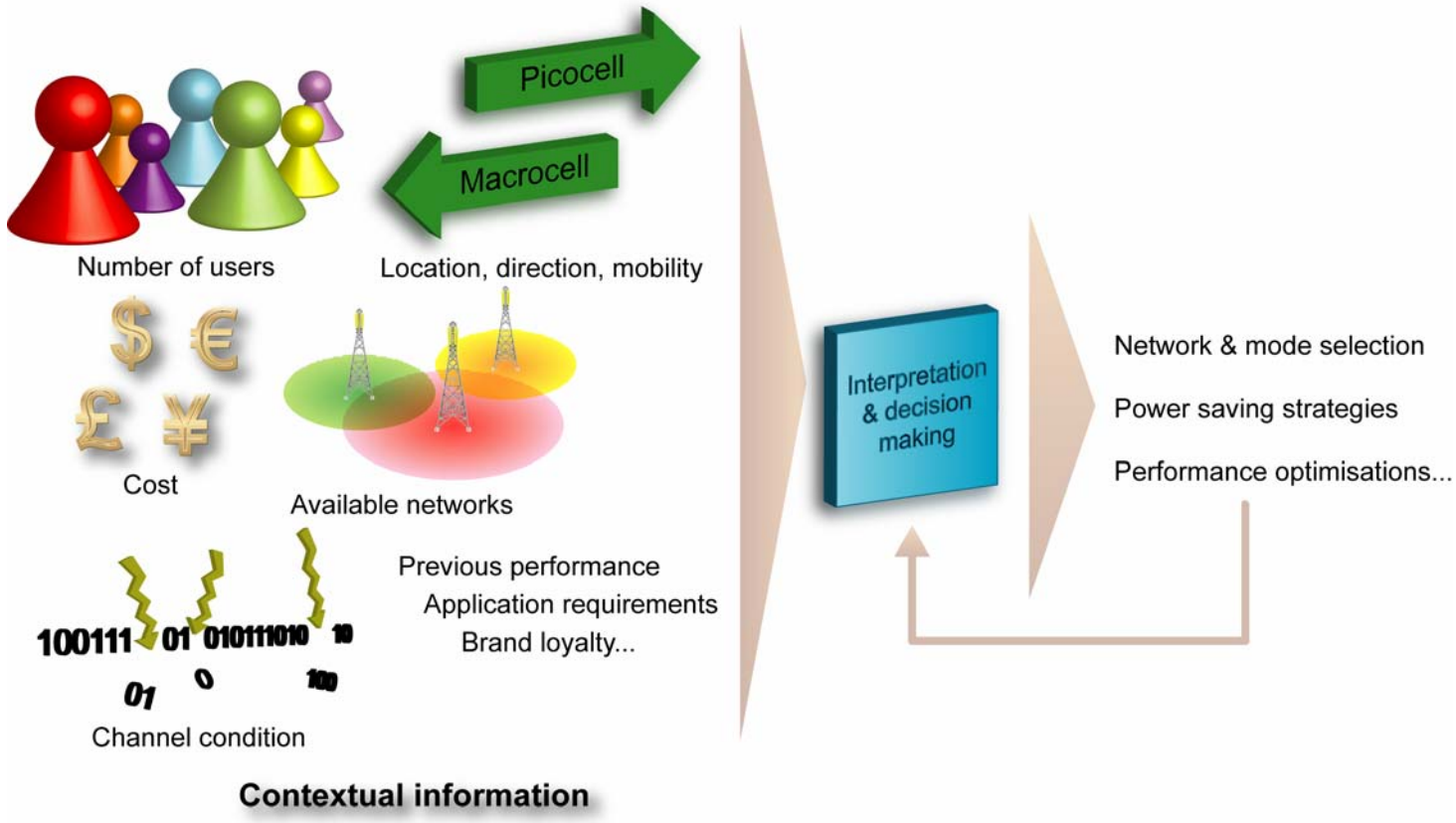


Benefits of reconfigurability



Realising the hype of cognitive radio

- Information is power- but only if you know how to use it!



In conclusion

- Learn from history
- Try not to ignore the little things
- UK's tradition of innovation
- Don't follow the crowd
- Don't listen to 'so called' experts
  - Listen to an expert who is also an *enthusiast*
- And one last thought…

Who should guide research?

- The best person to decide what research work shall be done is the person who is doing the research
- The next best person is the head of the department who knows all about the subject and the work
- After that you leave the field of the best people and start on increasingly worse groups
- The first of these being the research director, who is probably wrong more than half of the time
- Then the committee, which is wrong most of the time
- And finally, a committee of vice presidents, which is wrong all of the time

C E K Mees, former Director of Research, Eastman Kodak

Thank you for your attention

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